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**Takada et al.**

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(54) **OUTBOARD MOTOR STEERING CONTROL SYSTEM**

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(73) Assignee: **Honda Motor Co., Ltd.**, Tokyo (JP)

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***B63H 5/125*** (2006.01)
***B63H 20/08*** (2006.01)

(52) **U.S. Cl.** ..................................................... **440/61 S**

(58) **Field of Classification Search** ................... 440/53, 440/61 A, 61 B, 61 C, 61 G, 61 R, 61 S, 62, 440/63

See application file for complete search history.

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(57) **ABSTRACT**

An outboard motor steering control system is configured to have both an electric steering mechanism (having an electric motor, steering angle sensor and electronic controller such as microcomputer) and a hydraulic steering mechanism (having a hydraulic cylinder and a hydraulic pump) that can be switched therebetween in response to manipulation by the operator. With this, switching from one of the electric steering mechanism and hydraulic steering mechanism to the other can be easily conducted, thereby enabling to easily cope with the operator's preference of steering feel. Further, even if a failure occurs in one of the electric steering mechanism and hydraulic steering mechanism, the steering operation of the outboard motor can be continued by switching from the one steering mechanism to the other, i.e., normally-operating steering mechanism.

**21 Claims, 7 Drawing Sheets**

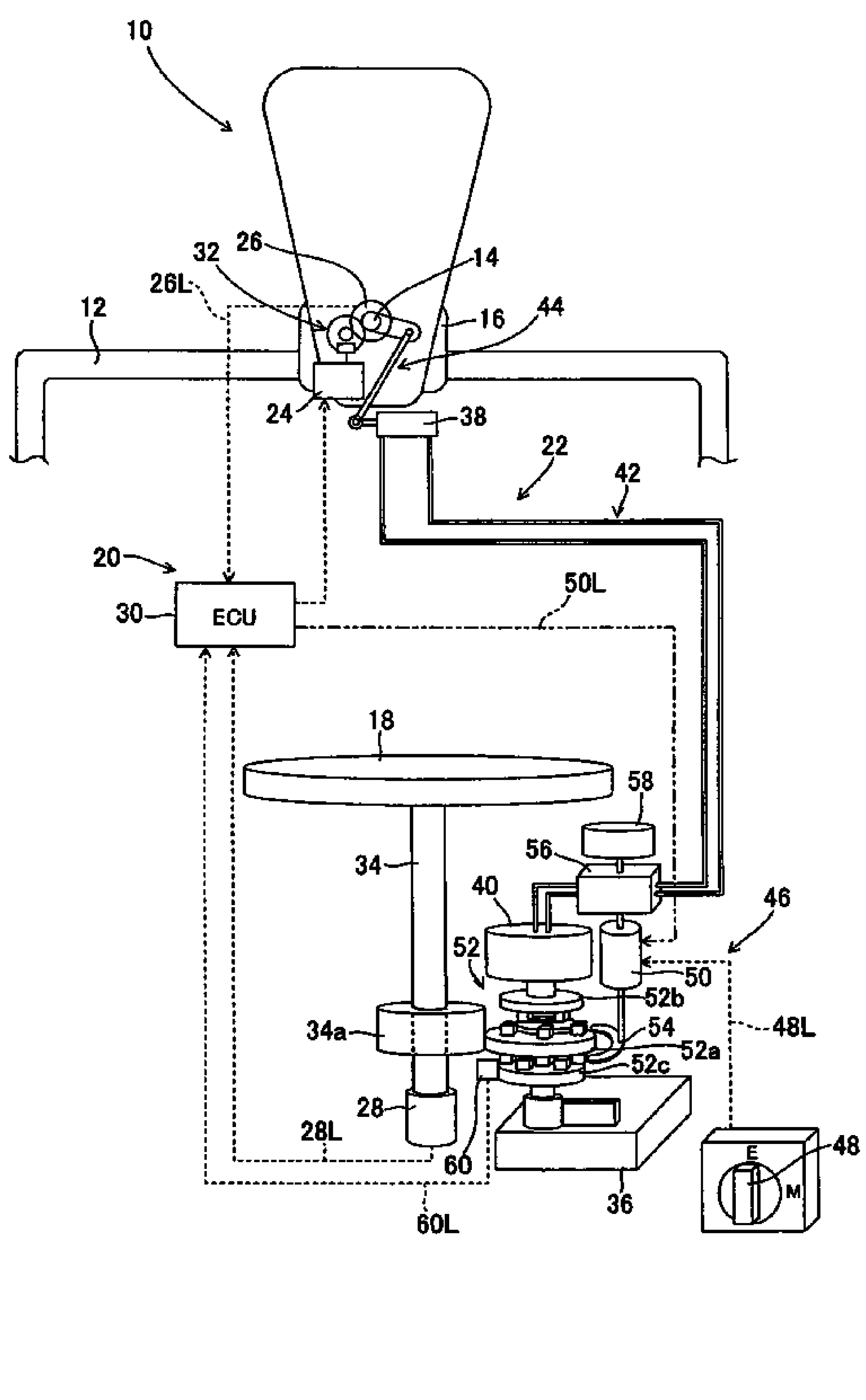
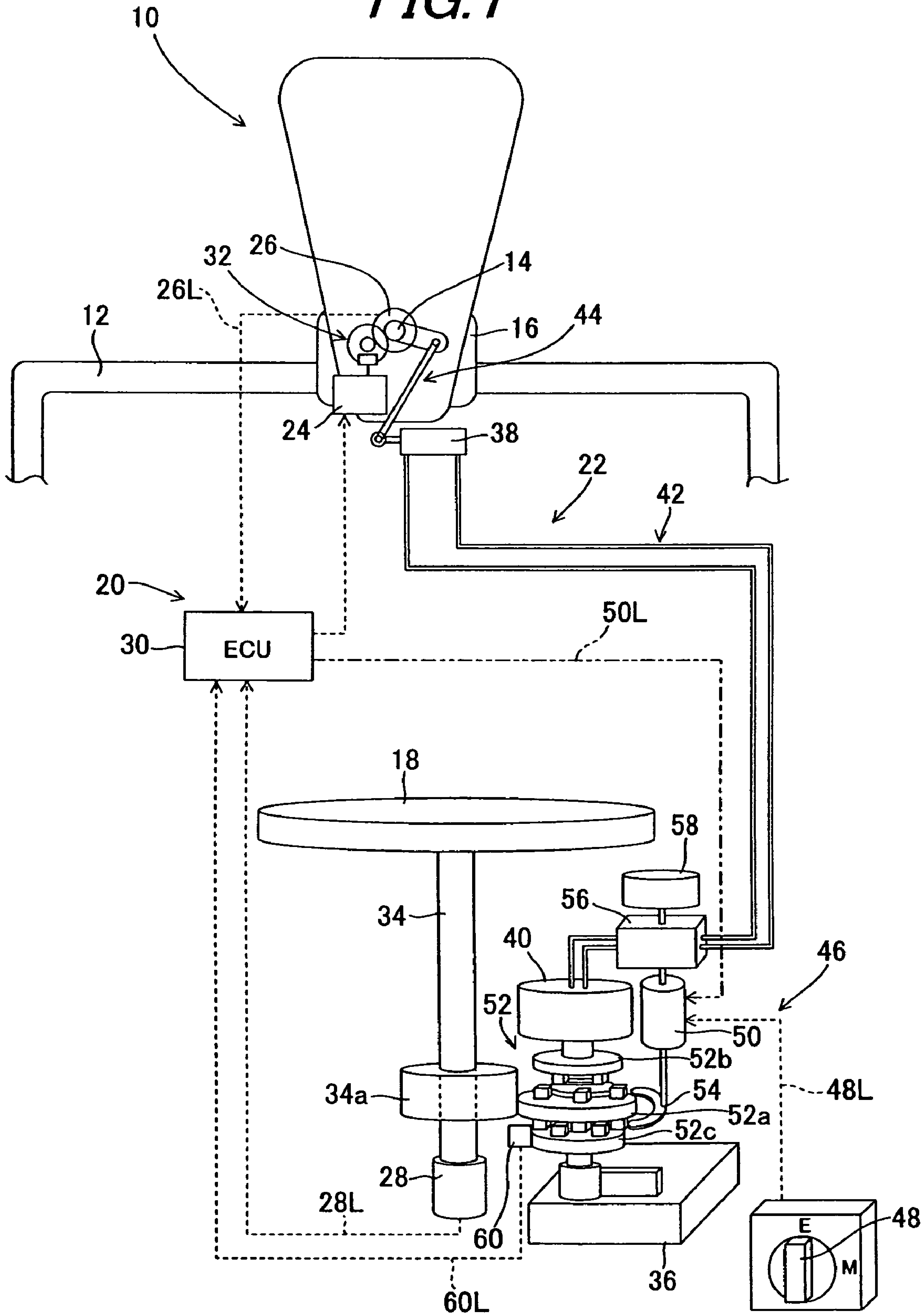


FIG. 1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12
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22
24
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26L
28
28L
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ECU
32
34
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36
38
40
42
44
46
48
48L
E
M
50
50L
52
52a
52b
52c
54
56
58
60
60L

FIG.2

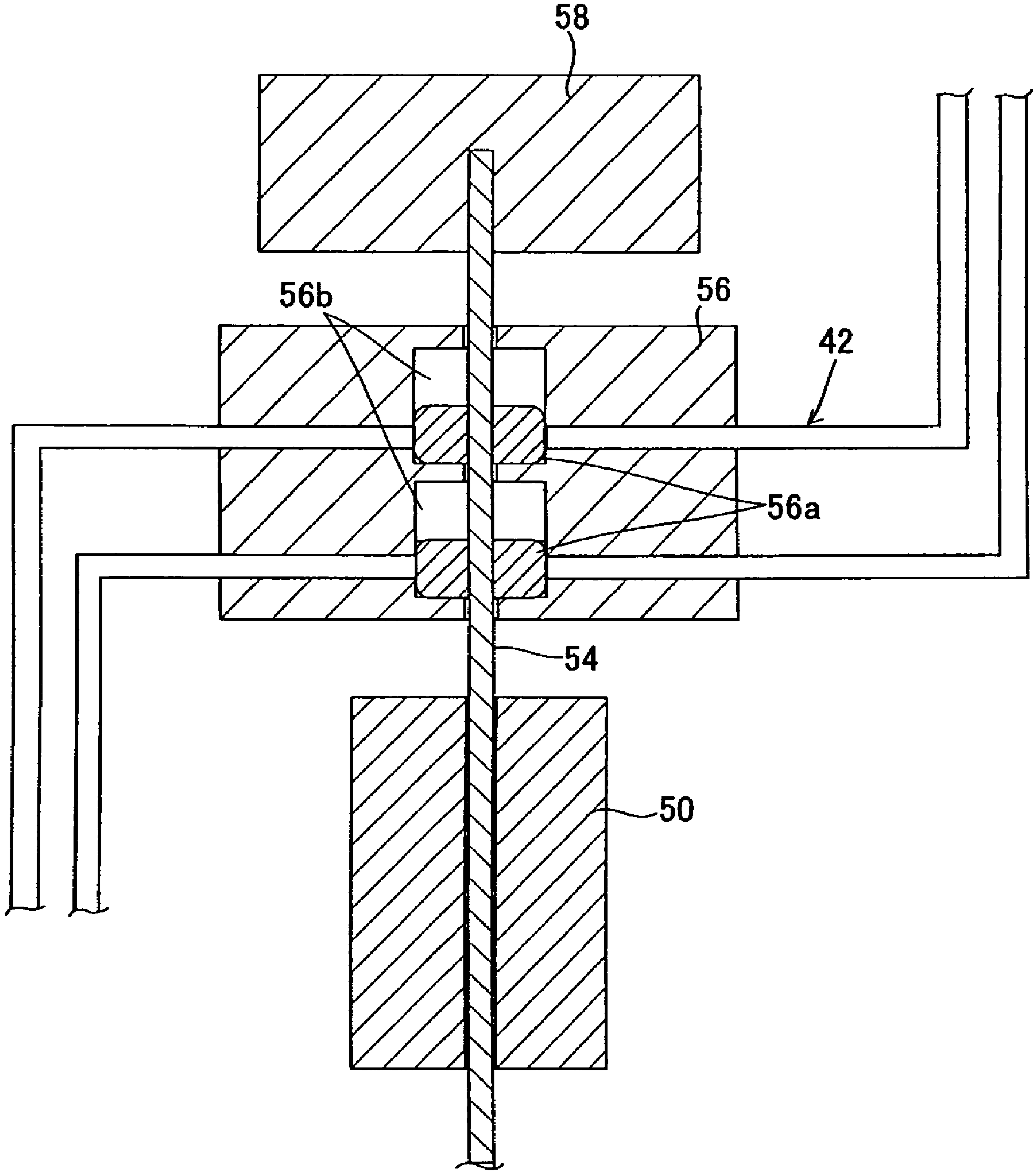


FIG. 3

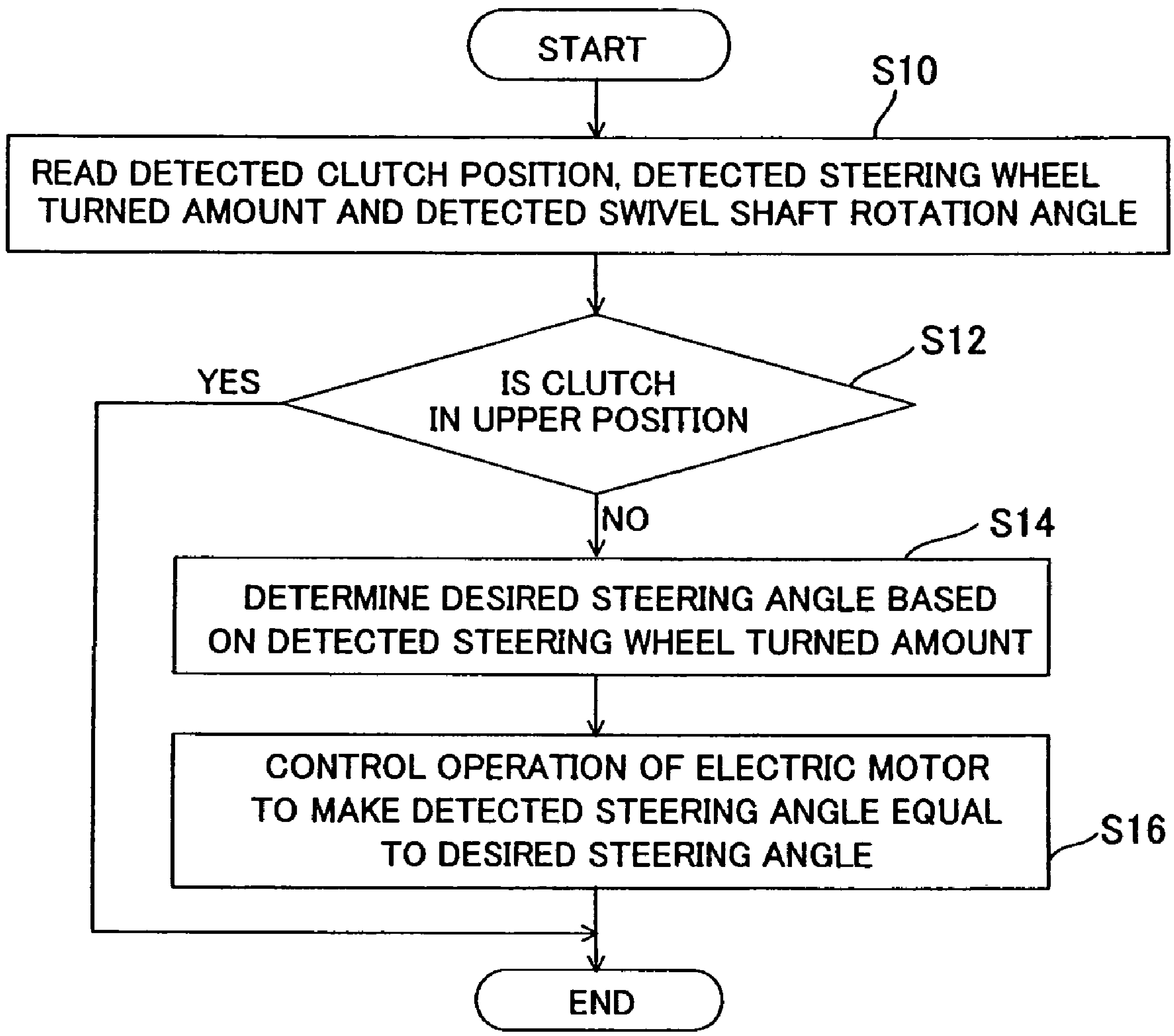

START
S10
READ DETECTED CLUTCH POSITION, DETECTED STEERING WHEEL TURNED AMOUNT AND DETECTED SWIVEL SHAFT ROTATION ANGLE
S12
IS CLUTCH IN UPPER POSITION
YES
NO
S14
DETERMINE DESIRED STEERING ANGLE BASED ON DETECTED STEERING WHEEL TURNED AMOUNT
CONTROL OPERATION OF ELECTRIC MOTOR TO MAKE DETECTED STEERING ANGLE EQUAL TO DESIRED STEERING ANGLE
S16
END

FIG.4

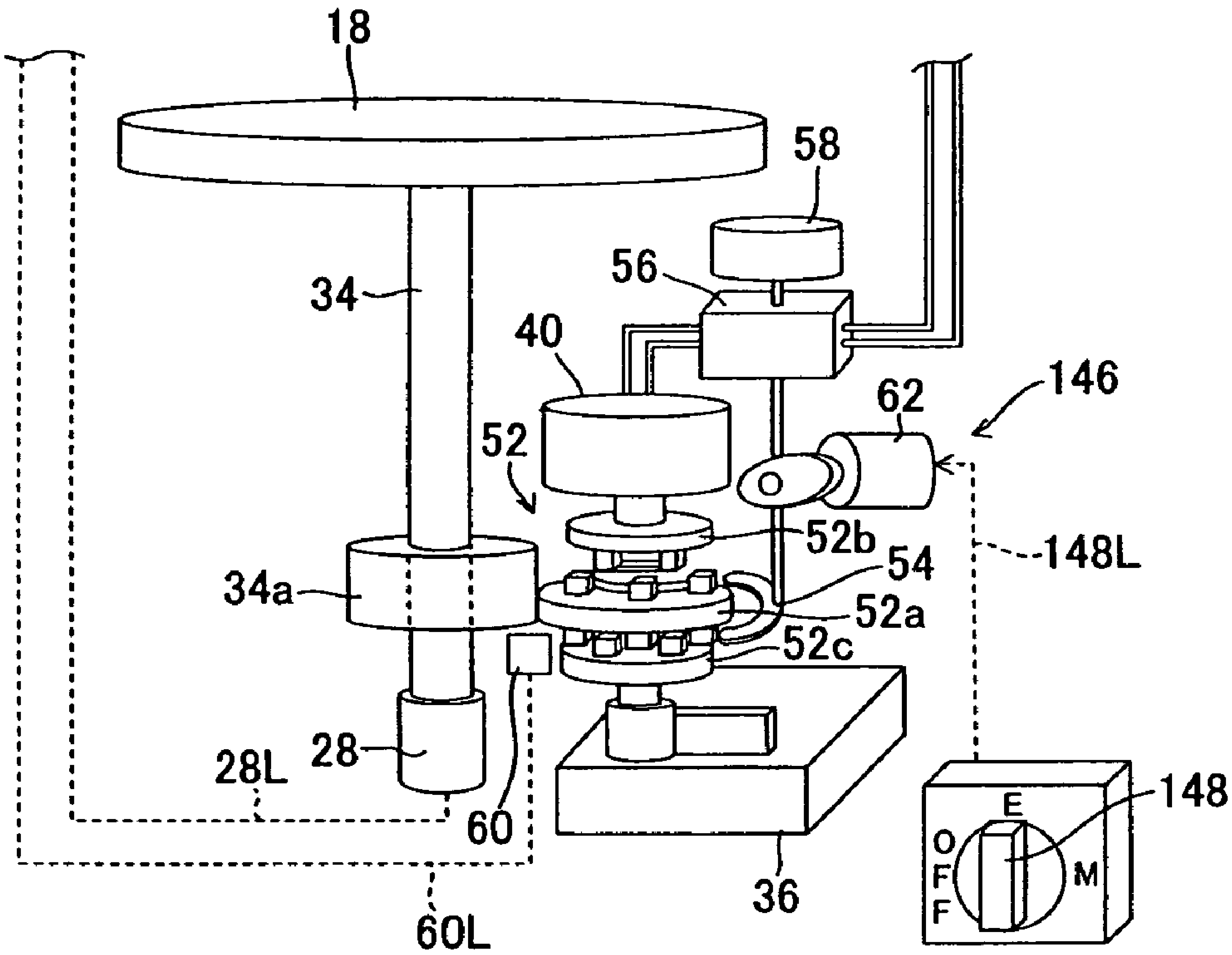

18
58
56
34
40
146
62
52
52b
148L
54
34a
52a
52c
28
28L
60
148
E
O
F
F
M
36
60L

FIG.5

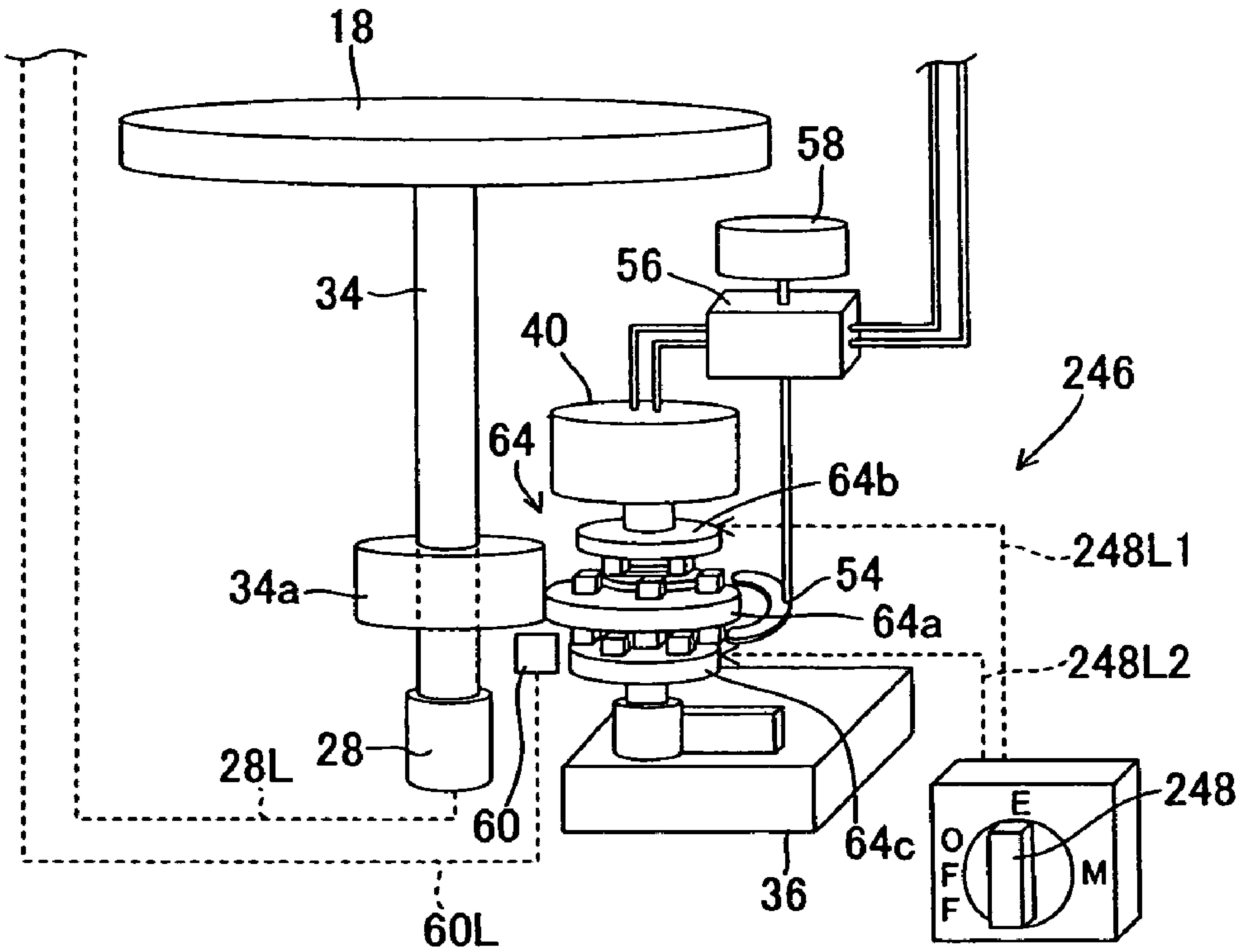

18
58
56
34
40
246
64
64b
248L1
54
34a
64a
248L2
28
28L
60
248
E
O
F
F
M
64c
36
60L

FIG.6

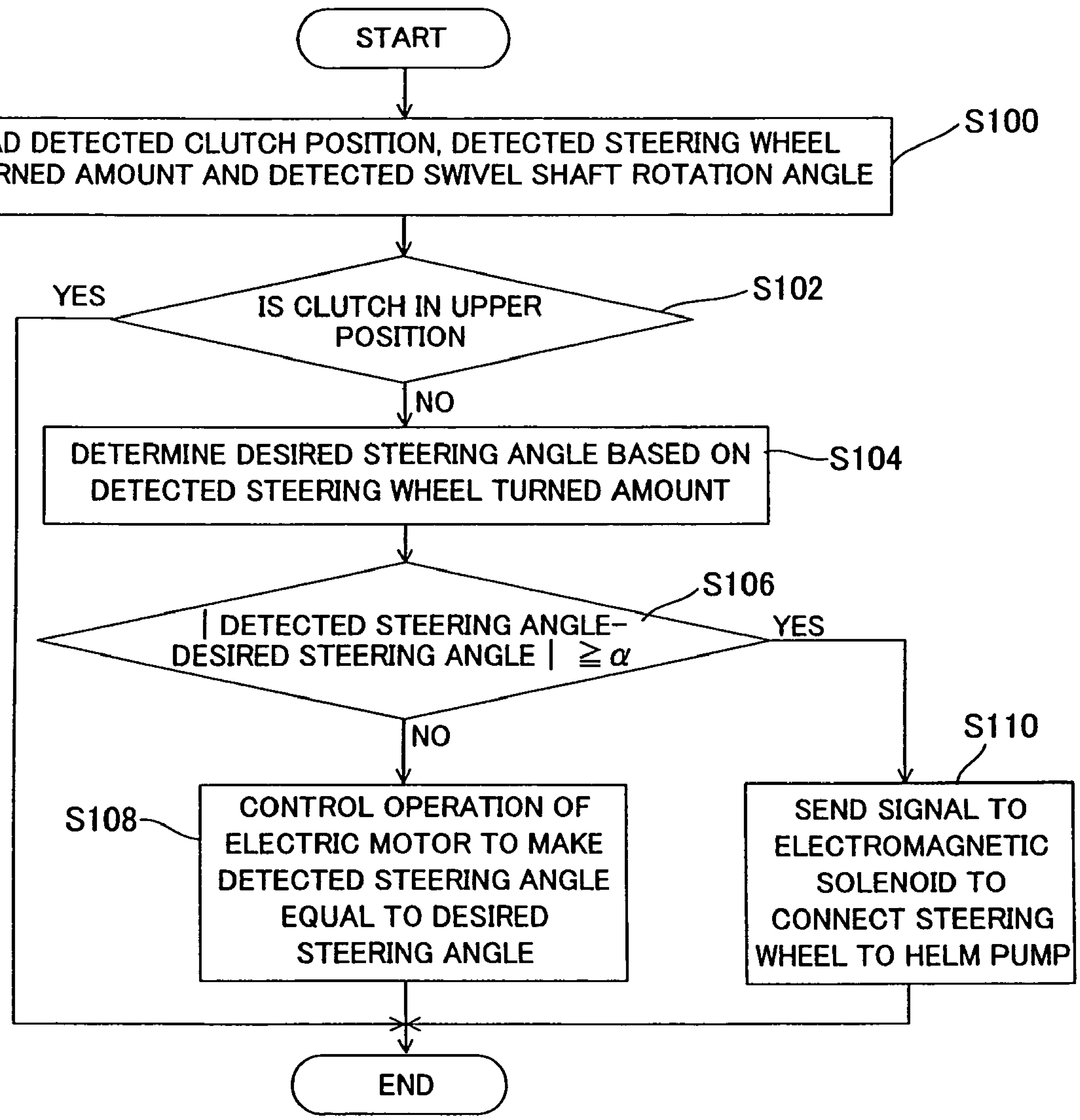

START
READ DETECTED CLUTCH POSITION, DETECTED STEERING WHEEL TURNED AMOUNT AND DETECTED SWIVEL SHAFT ROTATION ANGLE
S100
IS CLUTCH IN UPPER POSITION
S102
YES
NO
DETERMINE DESIRED STEERING ANGLE BASED ON DETECTED STEERING WHEEL TURNED AMOUNT
S104
| DETECTED STEERING ANGLE− DESIRED STEERING ANGLE | ≧ α
S106
YES
NO
S108
CONTROL OPERATION OF ELECTRIC MOTOR TO MAKE DETECTED STEERING ANGLE EQUAL TO DESIRED STEERING ANGLE
S110
SEND SIGNAL TO ELECTROMAGNETIC SOLENOID TO CONNECT STEERING WHEEL TO HELM PUMP
END

FIG. 7

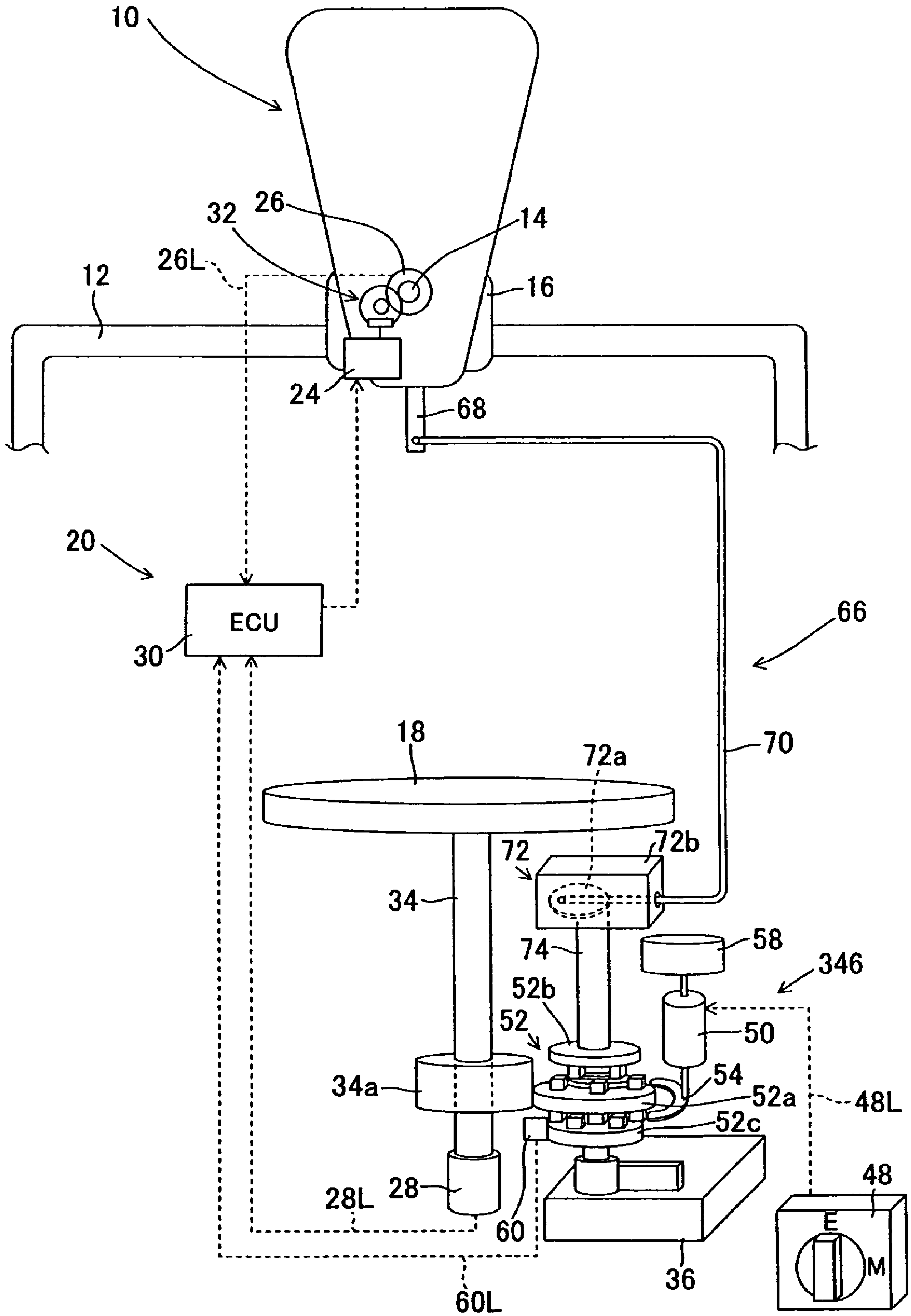
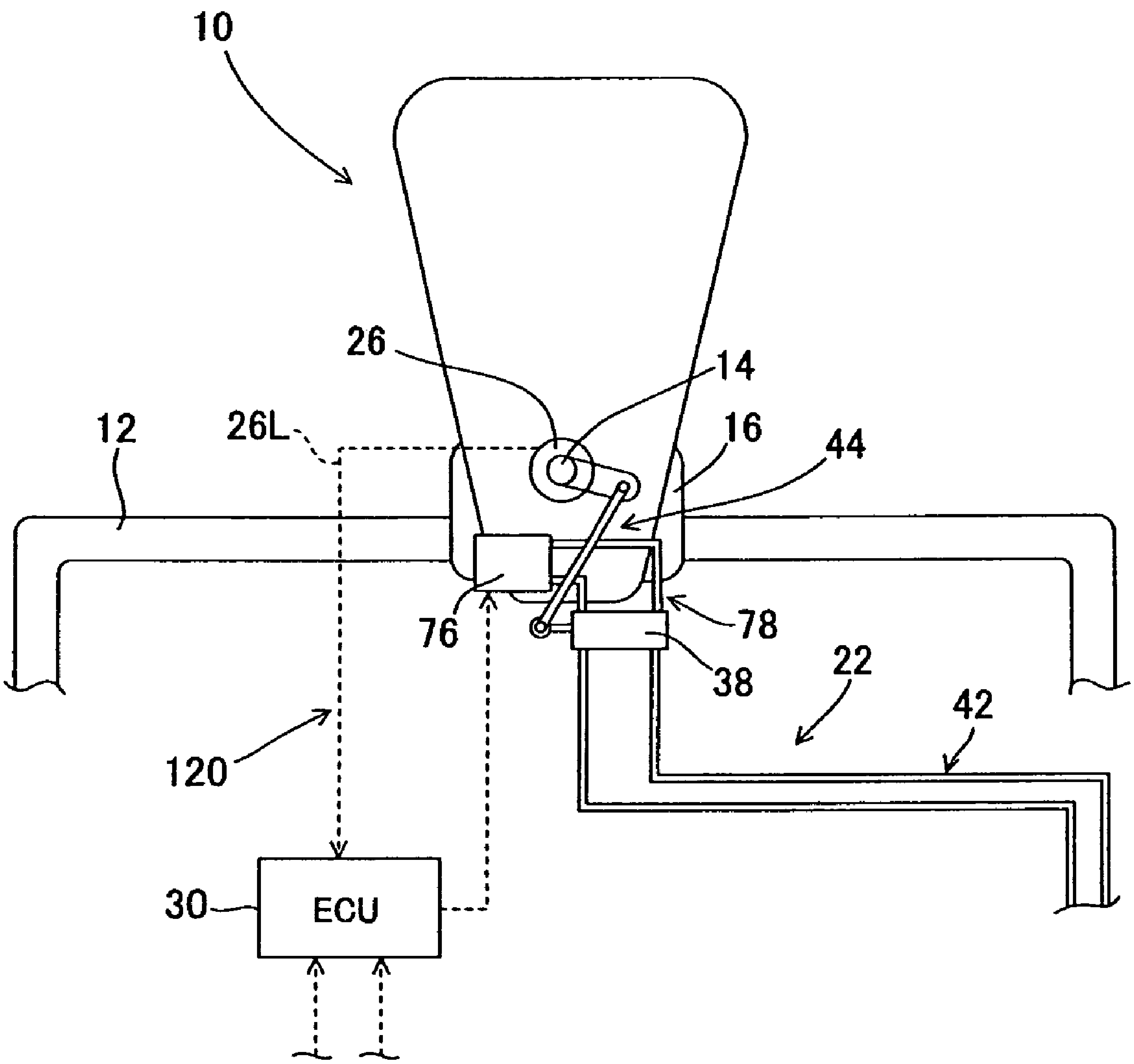

10
32
26
14
26L
12
16
24
68
20
ECU
30
66
70
18
72a
72
72b
34
74
58
346
52b
52
50
54
34a
52a
48L
52c
28
28L
60
48
E
M
36
60L

FIG.8



# OUTBOARD MOTOR STEERING CONTROL SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority under 35 USC 119 based on Japanese Patent Application No. 2006-042491, filed on Feb. 20, 2006, the entire disclosure of which is incorporated herein by reference.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an outboard motor steering control system.

2. Description of the Related Art

Conventionally, a hydraulic steering mechanism that is equipped with a hydraulic cylinder, utilizes a helm pump to discharge or delivery hydraulic oil by the amount in response to turning of a steering wheel and supplies the discharged oil via tubes to the hydraulic cylinder, thereby enabling to steer the outboard motor with respect to the hull (boat), is well-known as a type of steering systems of outboard motors, for example, as taught by Japanese Laid-Open Patent Application No. Sho 62(1987)-125996 (particularly in FIG. 2 etc.). In such a hydraulic steering mechanism, since an outboard motor and a steering wheel are mechanically connected, the operator can feel external force acting on the outboard motor from load of the steering wheel and can experience direct steering feel. This is also the same in a manual steering mechanism which steers an outboard motor through a push-pull cable in response to the operator's turning of a steering wheel.

Aside from the above, an electric steering mechanism is recently proposed which is equipped with an electric motor that is connected to a steering shaft of the outboard motor, detects turned amount of a steering wheel and controls the operation of the electric motor based on the detected rotation angle to steer the outboard motor with respect to the hull, for example, as taught by Japanese Laid-Open Patent Application No. 2002-187597 (particularly paragraphs 0011, 0025 and 0027 and FIG. 1). Since this type of the electric steering mechanism has no mechanical connection between the outboard motor and the steering wheel, even when the steering load of the outboard motor is heavy, the burden on the operator can advantageously be lightened, thereby enabling to achieve the facilitated operating feel.

However, since an outboard motor is normally provided with either the hydraulic steering mechanism or the electric steering mechanism, when the operator is not satisfied with the steering or operating feel, he/she must replace the mechanism to another or change the outboard motor as a whole, rendering difficult to cope with the operator's preference of steering feel. Further, in the case of occurrence of a steering mechanism failure, it is difficult to continue the steering operation of the outboard motor.

## SUMMARY OF THE INVENTION

An object of the invention is therefore to overcome the foregoing drawback by providing an outboard motor steering control system that easily satisfies the operator's preference of steering feel and enables to continue the steering operation of the outboard motor even when a steering mechanism failure occurs.



In order to achieve the object, the present invention provides a system for controlling steering of an outboard motor adapted to be mounted on a stern of a boat and having an internal combustion engine that powers a propeller, comprising: a steering wheel adapted to be installed at a cockpit of the boat to be turned by an operator; a steering shaft installed in the outboard motor through which the outboard motor can be steered relative to the boat; an electric steering mechanism having a steering wheel angle sensor which produces an output indicative of a turned amount of the steering wheel, a rotation angle sensor which produces an output indicative of a rotation angle of the steering shaft, an electric actuator which is adapted to rotate the outboard motor about the steering shaft, and a controller which controls operation of the electric actuator in response to the outputs of the steering wheel angle sensor and the rotation angle sensor such that the outboard motor is steered relative to the boat; a hydraulic steering mechanism having a hydraulic actuator which is adapted to rotate the outboard motor about the steering shaft and a hydraulic pump which supplies operating oil to the hydraulic actuator in response to turning of the steering wheel such that the outboard motor is steered relative to the boat; and a switch which switches steering control between the electric steering mechanism and the hydraulic steering mechanism in response to manipulation by an operator.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and advantages of the invention will be more apparent from the following description and drawings in which:

FIG. **1** is a schematic view of an outboard motor steering control system according to a first embodiment of the invention;

FIG. **2** is an enlarged sectional view showing a region of an oil-path opening/closing mechanism of the outboard motor steering control system shown in FIG. **1**;

FIG. **3** is a flowchart showing the operation of switching between an electric steering mechanism and hydraulic steering mechanism conducted by an ECU in the outboard motor steering control system shown in FIG. **1**;

FIG. **4** is a schematic view similar to FIG. **1** but partially showing an outboard motor steering control system according to a second embodiment of the invention;

FIG. **5** is a schematic view similar to FIG. **1** but partially showing an outboard motor steering control system according to a third embodiment of the invention;

FIG. **6** is a flowchart showing the operation of switching between an electric steering mechanism and a hydraulic steering mechanism conducted by an ECU in an outboard motor steering control system according to a fourth embodiment of the invention;

FIG. **7** is a schematic view similar to FIG. **1** but showing an outboard motor steering control system according to a fifth embodiment of the invention; and

FIG. **8** is a schematic view similar to FIG. **1** but partially showing an outboard motor steering control system according to a sixth embodiment of the invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An outboard motor steering control system according to preferred embodiments of the present invention will now be explained with reference to the attached drawings.

FIG. **1** is a schematic view of an outboard motor steering control system according to a first embodiment of the invention.

In FIG. **1**, reference numeral **10** indicates an outboard motor **10**. The outboard motor **10** is mounted on the stem or transom of a boat or hull **12**. Although not shown, the outboard motor is adapted to be mounted on a stem of the boat **12** and has an internal combustion engine that powers a propeller. Specifically, the outboard motor **10** is fastened to the stem through stem brackets **14** to be freely moved, i.e., steered about a swivel shaft **14**. A steering wheel **18** is installed near a cockpit or operator's seat of the boat **12**.

In the figure, reference numeral **20** indicates an electric steering mechanism and reference numeral **22** a hydraulic steering mechanism. The outboard motor steering control system according to the first embodiment comprises both of the electric steering mechanism **20** and hydraulic steering mechanism **22** as the steering mechanism of the outboard motor.

The electric steering mechanism **20** comprises an electric motor **24**, rotation angle sensor **26**, steering wheel angle sensor **28** and electronic control unit (ECU) **30**.

The electric motor **24** is installed in the outboard motor **10** and its rotational output is transmitted to the swivel shaft (steering shaft) **14** through a gear mechanism **32**. Specifically, rotation of the swivel shaft **14** generated by the motor **24** moves the outboard motor **10** to steer it relative to the boat **12**.

As shown in FIG. **1**, the rotation angle sensor **26** installed on the periphery of the swivel shaft **14** produces an output or signal indicative of rotating angle of the swivel shaft **14**, i.e., the steering angle of the outboard motor **10** relative to the boat **12**. The output of the rotation angle sensor **26** is sent to the ECU **30** via a signal line **26**L. The steering wheel angle sensor **28** is installed near a rotation shaft **34** connected to the steering wheel **18** and produces an output or signal indicative of turned amount (rotated angle) of the steering wheel **18** manipulated by the operator. The output of the steering wheel angle sensor **28** is also sent to the ECU **30** via a signal line **28**L.

The ECU **30** determines a desired steering angle of the outboard motor **10** based on the output of the steering wheel angle sensor **28** and controls the operation of the motor **24** such that the steering angle detected by the rotation angel sensor **26** becomes equal to the determined desired steering angle. The ECU **30** is disposed in the outboard motor **10**.

A steering load generator **36** is provided near the rotation shaft **34** of the steering wheel **18**. The steering load generator **36** is composed of a known hydraulic damper mechanism and generates load to the operator's turning manipulation of the steering wheel **18**. Since the electric steering mechanism **20** has no mechanical connection between the outboard motor **10** and the steering wheel **18**, the steering load generator **36** is provided to eliminate uncomfortable feel of the operator caused by the turning manipulation of the steering wheel **18** with no load. Details of the steering load generator **36** are described in Japanese Laid-Open Patent Application No. 2005-313823 proposed by the applicant earlier and the further explanation is omitted.

The hydraulic steering mechanism **22** comprises a hydraulic cylinder **38**, helm pump (hydraulic pump) **40** and hydraulic circuit **42**.

As shown in FIG. **1**, the hydraulic cylinder **38** is installed at the boat **12** and its reciprocating movement is transmitted to the swivel shaft **14** through a link mechanism **44**. Specifically, the cylinder **38** makes the swivel shaft **14** rotate to steer the outboard motor **10** relative to the boat **12**. The helm pump (hydraulic pump) **40** discharges or conveys operating oil by the amount in accordance with the turned amount of the steering wheel **18** into an oil path of the hydraulic circuit **42**. The discharged oil is supplied via the hydraulic circuit **42** to the cylinder **38** to make it reciprocate. The cylinder **38** is composed of a double-acting hydraulic cylinder.

In FIG. **1**, reference numeral **46** indicates a switching mechanism (switch) that switches the mechanism between the electric steering mechanism **20** and hydraulic steering mechanism **22**. The switching mechanism **46** switches from the electric steering mechanism **20** to the hydraulic steering mechanism **22**, and vice versa. The switching mechanism **46** is installed near the rotation shaft **34** of the steering wheel **18**.

The switching mechanism **46** comprises a tab switch **48**, electromagnetic solenoid **50** and clutch **52**. The tab switch **48** is disposed near the steering wheel **18** to be freely manipulated by the operator and connected to the solenoid **50** via a signal line **48**L. The tab switch **48** has two positions, i.e., an M position for energizing the solenoid **50** and an E position for de-energizing it and is manipulated to switch from one of the two positions to the other.

As shown in the figure, the clutch **52** is composed of three dog plates accumulated one above the other. A first dog plate **52***a* located middle of the three is disk-shaped and formed at each of its upper and lower surfaces with a plurality of dog teeth and at its circumferential surface with gear teeth (not shown) to be engaged with a gear **34***a* integrally rotating with the rotation shaft **34** of the steering wheel **18** to be freely rotated therewith, and is freely moved or slid vertically while keeping engagement with the gear **34***a*. The teeth width of the gear **34***a* of the steering wheel rotation shaft **34** in the direction of the shaft is appropriately determined in accordance with an amount of vertical movement of the first dog plate **52***a*.

A second dog plate **52***b* having dog teeth to be engaged with the dog teeth at the upper surface of the first dog plate **52***a* is rotatably installed above the first dog plate **52***a*. The second dog plate **52***b* is connected to the helm pump **40**. A third dog plate **52***c* having dog teeth to be engaged with the dog teeth at the lower surface of the first dog plate **52***a* is rotatably installed below the first dog plate **52***a*. The third dog plate **52***c* is connected to the steering load generator **36**.

The first dog plate **52***a* is connected to the electromagnetic solenoid **50** through a clutch shifter **54**. When the tab switch **48** is manipulated to the M position by the operator to energize the solenoid **50**, the solenoid **50** drives through the clutch shifter **54** the first dog plate **52***a* to move upward, thereby establishing engagement of the first dog plate **52***a* with the second dog plate **52***b*. On the other hand, when the tab switch **48** is manipulated to the E position by the operator to de-energize the solenoid **50**, the solenoid **50** drives through the clutch shifter **54** the first dog plate **52***a* to move downward, thereby establishing engagement of the first dog plate **52***a* with the third dog plate **52***c*.

Specifically, the clutch **52** is driven in response to the manipulation of the tab switch **48** by the operator to transmit turning of the steering wheel **18** to one of the helm pump **40** and steering load generator **36**. In other words, the clutch **52** is freely manipulated by the operator to make or release the connection between the rotation shaft **34** and helm pump **40**.

The solenoid **50** is installed at its upper portion with an oil-path opening/closing mechanism **56** for opening and closing the oil path of the hydraulic circuit **42**. In case that the connection between the rotation shaft **34** of the steering wheel **18** and the helm pump **40** is cut off, the operation of the helm pump **40** is prevented despite turning of the steering wheel **18** and, hence, the operating oil is not discharged. The oil-path opening/closing mechanism **56** is provided to ensure to prevent the operating oil from being discharged even if the helm pump **40** may operate due to a certain reason.

FIG. **2** is an enlarged sectional view showing a region of the oil-path opening/closing mechanism **56**.

The oil-path opening/closing mechanism **56** comprises valve members **56***a* each provided at the oil path of the hydraulic circuit **42** and housing members **56***b* housing the valve members **56***a*.

As shown in FIGS. **1** and **2**, the clutch shifter **54** penetrates the solenoid **50** and extends upward in the drawing sheet and the valve members **56***a* are attached to the extended clutch shifter **54**. With this structure, the valve members **56***a* are moved up and down in the housing members **56***b* in conjunction with the clutch **52**, i.e., the first dog plate **52***a*. Specifically, when the first dog plate **52***a* is driven to move upward to be engaged with the second dog plate **52***b*, each valve member **56***a* is moved upward in the housing member **56***b*, thereby making the oil path of the hydraulic circuit **42** opened or communicated. On the other hand, when the first dog plate **52***a* is driven to move downward to be engaged with the third dog plate **52***c*, each valve member **56***a* is moved downward in the housing member **56***b* to block communication of the oil path of the hydraulic circuit **42**.

A recirculation circuit (not shown) composed of a check valve is provided between the oil-path opening/closing mechanism **56** and hydraulic cylinder **38** in the hydraulic circuit **42**. Therefore, even when the oil path is blocked by the valve members **56***a*, the hydraulic cylinder **38** can be extended and contracted in response to external force, e.g., the force generated by the electric motor **24** of the electric steering mechanism **20**.

The clutch shifter **54** penetrates the oil-path opening/closing mechanism **56** and extends upward in the drawing sheet, as shown in FIGS. **1** and **2**. A manual knob **58** is attached at the extended end of the clutch shifter **54** to be freely manipulated by the operator. De-energizing the solenoid **50**, i.e., manipulating the tab switch **48** to the E position by the operator enables the manual knob **58** to be freely manipulated upward and downward. Specifically, the vertical manipulation of the manual knob **58** can drive the clutch **52** also, more exactly the first dog plate **52***a*, to establish or release the connection between the rotation shaft **34** of the steering wheel and the helm pump **40**.

As shown in FIG. **1**, the switching mechanism **46** comprises a clutch position sensor **60** composed of, for instance, an electromagnetic proximity switch. The clutch position sensor **60** is installed near the first dog plate **52***a* and produces an output or signal indicative of a position of the clutch **52**, more exactly the first dog plate **52***a*. The output of the clutch position sensor **60** is sent to the ECU **30** through a signal line **60**L. The ECU **30** controls the operation of the motor **24** of the electric steering mechanism **20** based on the output of the clutch position sensor **60**.

FIG. **3** is a flowchart showing the operation. The routine of this flowchart is activated in the ECU **30** at every predetermined interval, e.g., 100 milliseconds.

The explanation will be made in the following. In S**10**, detected position of the clutch **52**, i.e., first dog plate **52***a*, detected turned amount of the steering wheel **18** and detected rotation angle of the swivel shaft **14** are read.

The program proceeds to S**12** in which it is determined whether the clutch **52** is in the upper position, more specifically the first dog plate **52***a* of the clutch **52** is in position to be engaged with the second dog plate **52***b*, i.e., in the upper position. When the result in S**12** is No, specifically when it is determined that the first dog plate **52***a* is in position to be engaged with the third dog plate **52***c*, i.e., in the lower position, since this indicates that the steering mechanism has been switched to the electric steering mechanism **20**, the program proceeds to S**14** in which the desired steering angle of the outboard motor is determined based on the detected turned amount of the steering wheel **18**.

This determination is made by multiplying the detected turned amount of the steering wheel **18** by a predetermined ratio that is obtained by dividing the maximum steering angle in the left or right of the outboard motor by the number of turns of the steering wheel **18** within lock-to-lock positions.

Then the program proceeds to S**16** in which the electric motor **24** is driven to make the detected steering angle equal to the determined desired steering angle.

On the other hand, when the result in S**12** is Yes, i.e., when it is determined that the first dog plate **52***a* is in the upper position, since this indicates that the steering mechanism has been switched to the hydraulic steering mechanism **22**, S**14** and S**16** of the routine are skipped and the program is terminated.

Thus, the connection between the rotation shaft **34** of the steering wheel **18** and the helm pump **40** is established or released by the clutch **52** of the switching mechanism **46** and based on a position of the clutch **52**, more exactly the first dog plate **52***a*, the ECU **30** of the electric steering mechanism **20** controls the operation of the motor **24**. This structure makes it possible to achieve switching between the electric steering mechanism **20** and hydraulic steering mechanism **22** in response to manipulation by the operator.

In the outboard motor steering control system according to the first embodiment, it is configured to have both the electric steering mechanism **20** and the hydraulic steering mechanism **22** and also have the switching mechanism (switch) **46** that switches therebetween in response to manipulation by the operator. Specifically, the switching mechanism **46** is configured to include includes a driver (comprising the tab switch **48** disposed to be freely manipulated by the operator and the electromagnetic solenoid **50** which is energized/de-energized in response to manipulation of the tab switch by the operator), and the clutch **52** is configured to disconnect the helm (hydraulic) pump **40** from the hydraulic cylinder (actuator) **38** in response to manipulation of the driver by the operator such that the hydraulic steering actuator (**38**) becomes inoperative.

With this, switching from one of the electric steering mechanism **20** and hydraulic steering mechanism **22** to the other can be easily conducted, thereby enabling to easily cope with the operator's preference of steering feel. Further, even when a failure occurs in one of the electric steering mechanism **20** and hydraulic steering mechanism **22**, the steering operation of the outboard motor can be continued by switching from the one steering mechanism to the other, i.e., normally-operating steering mechanism.

Further, since it is configured such that the switching mechanism **46** comprises the clutch **52** that establishes or releases the connection between the rotation shaft **34** of the steering wheel **18** and the helm pump **40**, oil-path opening/closing mechanism **56** that opens and closes the oil path of the hydraulic circuit **42** in conjunction with the clutch **52** and the clutch position sensor **60** that detects a position of the clutch **52**, i.e., the first dog plate **52***a*, and the ECU **30** controls the operation of the motor **24** based on a position of the clutch **52**, it becomes possible to easily and reliably switch from one of the electric steering mechanism **20** and hydraulic steering mechanism **22** to the other with simple structure.

Furthermore, it is configured such that the clutch **52** is driven by one of the electromagnetic solenoid **50** and manual knob **58**, thereby enhancing flexibility in design of the switching mechanism **46**.

Further, it is configured such that the motor **24** rotates the swivel shaft **14** through the gear mechanism **44** to steer the outboard motor **10** relative to the boat **12**, thereby enabling to make the electric steering mechanism **20** simple in its structure.

Next, an outboard motor steering control system according to a second embodiment will be explained.

FIG. **4** is a schematic view similar to FIG. **1** but partially showing the outboard motor steering control system according to the second embodiment. Note that constituent elements corresponding to those of the first embodiment are assigned by the same reference symbols as those in the first embodiment and will not be explained.

The explanation will be made with focus on points of difference from the first embodiment. In the second embodiment, the switching mechanism **46** is replaced by a switching mechanism (switch) **146** that is partially different from the switching mechanism. Specifically, the switching mechanism **146** is equipped with an electric motor **62** in place of the electromagnetic solenoid **50**. The switching mechanism **146** having this electric motor **62** will be explained below.

In addition to this electric motor **62**, the switching mechanism **146** has a tab switch **148** and clutch **52**.

The tab switch **148** is connected to the electric motor **62** through a signal line **148**L. The tab switch **148** has three positions, i.e., an E position for energizing the electric motor **62** to rotate clockwise, an M position for energizing it to rotate counterclockwise and an OFF position for de-energizing it, and is manipulated by the operator to conduct switching among the three positions.

The first dog plate **52***a* of the clutch **52** is connected via the clutch shifter **54** to the output shaft of the electric motor **62**. When the tab switch **148** is manipulated to the M position by the operator, the electric motor **62** drives through the clutch shifter **54** the first dog plate **52***a* to move upward, thereby establishing engagement of the first dog plate **52***a* with the second dog plate **52***b*. On the other hand, when the tab switch **148** is manipulated to the E position by the operator, the electric motor **62** drives through the clutch shifter **54** the first dog plate **52***a* to move downward, thereby establishing engagement of the first dog plate **52***a* with the third dog plate **52***c*. When the tab switch **148** is manipulated to the OFF position by the operator, the aforementioned manual knob **58** can be freely manipulated up and down.

In the second embodiment, similarly to the first embodiment, the clutch **52** is driven by the manual knob **58**. The remaining configuration including the electric steering mechanism **20** and hydraulic steering mechanism **22** is also the same as that in the first embodiment.

Since the outboard motor steering control system according to the second embodiment is thus configured to drive the clutch **52** using the switching mechanism **146** equipped with the electric motor **62**, it can provide the same effects as those explained regarding the first embodiment.

Next, an outboard motor steering control system according to a third embodiment will be explained.

FIG. **5** is a schematic view similar to FIG. **1** but partially showing the outboard motor steering control system according to the third embodiment. Also, constituent elements corresponding to those of the first embodiment are assigned by the same reference symbols as those in the first embodiment and will not be explained.

The explanation will be made with focus on points of difference from the first embodiment. In the third embodiment, the switching mechanism **46** is replaced by a switching mechanism (switch) **246** that is partially different therefrom. Specifically, the switching mechanism **246** is equipped with an electromagnetic clutch **64** in place of the electromagnetic solenoid **50** and clutch **52**. The switching mechanism **246** having the electromagnetic clutch **64** will be explained below.

The switching mechanism **246** comprises a tab switch **248** and the electromagnetic clutch **64**.

As shown in FIG. **5**, the electromagnetic clutch **64** is composed of three electromagnetic dog plates accumulated one above the other. A first electromagnetic dog plate **64***a* located middle among three, second electromagnetic dog plate **64***b* located thereabove and third electromagnetic dog plate **64***c* located therebelow are the same in shape as the first, second and third dog plates **52***a*, **52***b* and **52***c* of the clutch **52** in the first embodiment. The clutch **64** is, however, different from the clutch **52** in the first embodiment in that the second and third electromagnetic dog plates **64***b* and **64***c* are energized to generate magnetic suction power, thereby driving the first electromagnetic dog plate **64***a* up and down.

The second and third electromagnetic dog plates **64***b* and **64***c* are connected to the tab switch **248** through signal lines **248**L**1** and **248**L**2**, respectively. The tab switch **248** has three positions, i.e., an E position for de-energizing the second electromagnetic dog plate **64***b*, while energizing the third electromagnetic dog plate **64***c*, an M position for energizing the second electromagnetic dog plate **64***b*, while de-energizing the third electromagnetic dog plate **64***c*, and an OFF position for de-energizing both the second and third electromagnetic dog plates **64***b*, **64***c*, and is manipulated by the operator to conduct switching among the three positions.

When the tab switch **248** is manipulated to the M position by the operator, magnetic attraction is generated in the second electromagnetic dog plate **64***b* to move the first electromagnetic dog plate **64***a* upward, thereby establishing engagement of the first electromagnetic dog plate **64***a* with the second electromagnetic dog plate **64***b*. When the tab switch **248** is manipulated to the E position, the generated magnetic attraction in the third electromagnetic dog plate **64** moves the first electromagnetic dog plate **64***a* downward, thereby establishing engagement of the first electromagnetic dog plate **64***a* with the third electromagnetic dog plate **64***c*. When the tab switch **248** is manipulated to the OFF position by the operator, the aforementioned manual knob **58** can be freely manipulated up and down.

In the third embodiment, similarly to the first embodiment, the electromagnetic clutch **64** is driven by the manual knob **58**. The remaining configuration including the electric steering mechanism **20** and hydraulic steering mechanism **22** is also the same as that in the first embodiment.

Since the outboard motor steering control system according to the third embodiment is thus configured such that the clutch of the switching mechanism **246** comprises the electromagnetic clutch **64**, it can provide the same effects as those explained regarding the first embodiment. Further, the electromagnetic clutch **64** is operated directly in response to a position of the tab switch **248**, thereby enabling to make the switching mechanism **246** still simpler in structure than the switching mechanism **46** in the first embodiment.

Next, an outboard motor steering control system according to a fourth embodiment will be explained.

The explanation will be made with focus on points of difference from the first embodiment. In the fourth embodiment, the ECU **30** is connected to the electromagnetic solenoid **50** through a signal line **50**L, as indicated by a phantom line in FIG. **1**, such that the ECU **30** can conduct switching between the electric steering mechanism **20** and hydraulic steering mechanism **22** in addition to the switching operation by the operator.

FIG. **6** is a flowchart similar to FIG. **3** showing the operation.

The program is executed similarly to S**10** to S**14**. Specifically, the program starts in S**100** in which detected position of the clutch **52**, i.e., first dog plate **52***a,* detected turned amount of the steering wheel **18** and detected rotation angle of the swivel shaft **14** are read and proceeds to S**102** in which it is determined whether the first dog plate **52***a* is in the upper position. When the result in S**102** is No, it is determined that the steering mechanism has been switched to the electric steering mechanism **20**, the program proceeds to S**104** in which the desired steering angle is determined base on the detected turned amount of the steering wheel **18** and then proceeds to S**106**.

In S**106**, it is determined whether an error between the detected steering angle of the swivel shaft **14** and determined desired steering angle is equal to or greater than a predetermined value $\alpha$ (e.g., 5 degrees) in absolute value. When the result in S**106** is No, it is determined that the operation of the electric steering mechanism **20** is normal and the program proceeds to S**108**.

In S**108**, similarly to S**16**, the electric motor **24** is driven to make the detected steering angle equal to the determined desired steering angle. On the other hand, when the result in S**106** is Yes, it is determined that a failure has occurred in the electric steering mechanism **20** and the program proceeds to S**110**.

In S**110**, the electromagnetic solenoid **50** is sent, via the signal line **50**L, with a signal for driving the first dog plate **52***a* upward, such that the rotation shaft **34** of the steering wheel **18** is connected to the helm pump **40**. In the next routine onward, unless the clutch **52** is manipulated by the operator, the result in S**102** is to be Yes and it is switched from the electric steering mechanism **20** to the hydraulic steering mechanism **22**.

The remaining configuration including the electric steering mechanism **20**, hydraulic steering mechanism **22** and switching mechanism **46** is the same as those in the first embodiment.

Since the outboard motor steering control system according to the fourth embodiment is thus configured to have both the electric steering mechanism **20** and hydraulic steering mechanism **22** and configured such that the ECU **30** conducts switching between the electric steering mechanism **20** and hydraulic steering mechanism **22**, when a failure occurs in the electric steering mechanism **20**, it is possible to immediately switch to the hydraulic steering mechanism **22**, thereby enabling to continue the steering operation of the outboard motor.

An outboard motor steering control system according to a fifth embodiment of the invention will now be explained.

FIG. **7** is a schematic view similar to FIG. **1** showing the outboard motor steering control system according to the fifth embodiment. Also, constituent elements corresponding to those of the first embodiment are assigned by the same reference symbols as those in the first embodiment and will not be explained.

The explanation will be made with focus on points of difference from the first embodiment. In the fifth embodiment, the hydraulic steering mechanism **22** is replaced by a manual steering mechanism **66**. Along with the change to the manual steering mechanism **66**, instead of the switching mechanism **46**, a switching mechanism (switch) **346** that is partially different from the mechanism **46** is provided.

Specifically, as shown in FIG. **7**, it is configured such that the manual steering mechanism **66** is installed, and the hydraulic cylinder **38**, helm pump **40**, hydraulic circuit **42** and link mechanism **44** are removed. More specifically, the switching mechanism **346** is like the switching mechanism **46**, but the oil-path opening/closing mechanism **56** is removed therefrom. The manual steering mechanism **66** will be explained below.

The manual steering mechanism **66** comprises a stay **68** installed in the outboard motor, a push-pull cable **70** connected to the stay **68** and a driving mechanism **72** that drives the push-pull cable **70** in response to turning of the steering wheel **18**.

As shown in FIG. **7**, the driving mechanism **72** is composed of a member **72***a* having elliptical-plate shape and a housing member **72***b* housing the member **72***a*. The member **72***a* is connected at one end with a rotation shaft **74** that is connected to the second dog plate **52***b* of the clutch **52** to rotate integrally therewith, and is connected at the other end with one end of the push-pull cable **70**. The other end of the push-pull cable is connected to the stay **68** through a hole formed in the housing member **72***b*.

In the switching mechanism **346**, similarly to the first embodiment, the clutch **52**, more exactly the first dog plate **52***a* is driven by the electromagnetic solenoid or manual knob **58**. When the first dog plate **52***a* is driven to move upward to be engaged with the second dog plate **52***b,* turning of the steering wheel **18** is transferred through the rotation shaft **74**, driving mechanism **72** and push-pull cable **70** to the stay **68** to move it. The movement of the stay **68** makes the swivel shaft **14** rotate, thereby steering the outboard motor **10** relative to the boat **12**. The remaining configuration including the electric steering mechanism **20** and the like is the same as that in the first embodiment.

Since the outboard motor steering control system according to the fifth embodiment is thus configured to have both the electric steering mechanism **20** and manual steering mechanism **66** and further have the switching mechanism **346** to conduct switching therebetween in response to manipulation by the operator, switching from one of the electric steering mechanism **20** and manual steering mechanism **66** to the other can be easily conducted, thereby enabling to easily cope with the operator's preference of steering feel. Further, even when a failure occurs in one of the electric steering mechanism **20** and manual steering mechanism **66**, the steering operation of the outboard motor can be continued by switching from the one steering mechanism to the other, i.e., normally-operating steering mechanism.

Next, an outboard motor steering control system according to a sixth embodiment will be explained.

FIG. **8** is a schematic view similar to FIG. **1** but partially showing the outboard motor steering control system according to the sixth embodiment. Similarly, constituent elements corresponding to those of the first embodiment are assigned by the same reference symbols as those in the first embodiment and will not be explained.

The explanation will be made with focus on points of difference from the first embodiment. In the sixth embodiment, the electric steering mechanism **20** is replaced by an electric steering mechanism **120** that is partially different the mechanism **20**. Specifically, an electrically-operated hydraulic pump **76** is provided in place of the electric motor **24** and gear mechanism **32** of the electric steering mechanism **20**. The electric steering mechanism **120** equipped with the electrically-operated hydraulic pump **76** will be explained below.

In the electric steering mechanism **120**, the hydraulic pump **76** is connected to the hydraulic cylinder **38** through the hydraulic circuit **78**. Specifically, the electric steering mechanism **120** uses the hydraulic pump **76** to drive the hydraulic cylinder **38** of the hydraulic steering mechanism **22**, thereby rotating the swivel shaft **14** through the link mechanism **44** to steer the outboard motor **10** relative to the boat **12**.

The remaining configuration including the electric steering mechanism **20**, switching mechanism **46** and the like is the same as those in the first embodiment.

Since the outboard motor steering control system according to the sixth embodiment is thus configured to have both the electric steering mechanism **120** and hydraulic steering mechanism **22** and further have the switching mechanism **46** to conduct switching therebetween in response to manipulation by the operator, it can provide the same effects as that explained regarding the first embodiment. In addition, since it is configured such that the electrically-operated hydraulic pump **76** of the electric steering mechanism **120** is operated to steer the outboard motor **10** through the hydraulic cylinder **38** of the hydraulic steering mechanism **22**, i.e., the hydraulic cylinder **38** is used in common, even though the outboard motor steering mechanism is equipped with both the electric steering mechanism **120** and hydraulic steering mechanism **22**, the number of components can be decreased.

The present exemplary embodiments are thus configured to have a system for controlling steering of an outboard motor (**10**) adapted to be mounted on a stem of a boat (**12**) and having an internal combustion engine that powers a propeller, comprising: a steering wheel (**18**) adapted to be installed at a cockpit of the boat to be turned by an operator; a steering shaft (swivel shaft **14**) installed in the outboard motor through which the outboard motor can be steered relative to the boat; an electric steering mechanism (**20**) having a steering wheel angle sensor (**28**) which produces an output indicative of a turned amount of the steering wheel, a rotation angle sensor (**26**) which produces an output indicative of a rotation angle of the steering shaft, an electric actuator (electric motor **24**) which is adapted to rotate the outboard motor about the steering shaft, and a controller (ECU **30**) which controls operation of the electric actuator in response to the outputs of the steering wheel angle sensor and the rotation angle sensor such that the outboard motor is steered relative to the boat; a hydraulic steering mechanism (**22**) having a hydraulic actuator (hydraulic cylinder **38**) which is adapted to rotate the outboard motor about the steering shaft and a hydraulic pump (helm pump **40**) which supplies operating oil to the hydraulic actuator in response to turning of the steering wheel such that the outboard motor is steered relative to the boat; and a switch (switching mechanism **46**, **146**, **246**) which switches the mechanism between the electric steering mechanism and the hydraulic steering mechanism in response to manipulation by an operator.

In the system, the switch includes: a driver (electromagnetic solenoid **50**; electric motor **62**, tab switch **48**, manual knob **58**) disposed to be freely manipulated by the operator; and a clutch (**52**, electromagnetic clutch **64**) which disconnects the hydraulic pump from the hydraulic actuator in response to manipulation of the driver by the operator such that the hydraulic steering mechanism becomes inoperative.

In the system, the driver includes; a tab switch (**48**) disposed to be freely manipulated by the operator; and an electromagnetic solenoid (**50**) which is energized/de-energized in response to manipulation of the tab switch by the operator; and the clutch disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the tab switch.

In the system, the driver includes; a manual knob (**58**) disposed to be freely manipulated by the operator; and the clutch (**52**) disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the manual knob.

The system further includes: an oil-path opening/closing mechanism (**56**) which closes an oil path (in a hydraulic circuit **42**) connecting the hydraulic pump and the hydraulic actuator when the clutch disconnects the hydraulic pump from the hydraulic actuator.

In the system, the driver includes; a tab switch (**148**) disposed to be freely manipulated by the operator; and an electric motor (**62**) which is rotated in response to manipulation of the tab switch by the operator; and the clutch (**52**) disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the tab switch.

In the system, the driver includes; a tab switch (**248**) disposed to be freely manipulated by the operator; and the clutch (electromagnetic clutch **64**) disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the tab switch.

The system further includes: a clutch position sensor (**60**) which produces an output indicative of a position of the clutch; and the controller (ECU **30**) determines whether the hydraulic actuator is in operation based on the output of the clutch position sensor (S**10**, S**12**, S**100**, S**102**).

The present exemplary embodiments are thus configured to have a system for controlling steering of an outboard motor (**10**) adapted to be mounted on a stem of a boat (**12**) and having an internal combustion engine that powers a propeller, comprising: a steering wheel (**18**) installed at a cockpit of the boat to be turned by an operator; a steering shaft (swivel shaft **14**) installed in the outboard motor through which the outboard motor can be steered relative to the boat; an electric steering mechanism (**20**) having a steering wheel angle sensor (**28**) which produces an output indicative of a turned amount of the steering wheel, a rotation angle sensor (**26**) which produces an output indicative of a rotation angle of the steering shaft, an electric actuator (electric motor **24**) which is adapted to rotate the outboard motor about the steering shaft, and a controller (ECU **30**) which determines a desired steering angle based on the output of the steering wheel angle sensor and controls operation of the electric actuator to steer the outboard motor relative to the boat such that a detected steering angle detected from the output of the rotation angle sensor becomes equal to the desired steering angle (S**10** to S**16**, S**100** to S**110**); a hydraulic steering mechanism (**22**) having a hydraulic actuator (hydraulic cylinder **38**) which is adapted to rotate the outboard motor about the steering shaft and a hydraulic pump (helm pump **40**) which supplies operating oil to the hydraulic actuator in response to turning of the steering wheel such that the outboard motor is steered relative to the boat; and a switch (switching mechanism **46**, **146**, **246**) which switches the mechanism between the electric steering mechanism and the hydraulic steering mechanism in response to manipulation by an operator.

In the system, the controller (ECU **30**) determines whether an error between the detected steering angle and the desired angle is equal to or greater than a predetermined value ($\alpha$) (S**104**, S**106**), and operates the switch in response to the determination (S**108**, S**110**).

In the system, the controller (ECU **30**) determines that a failure has occurred in the electric steering mechanism when the error is equal to or greater than the predetermined value S**106**), and operates the switch to switch the mechanism from the electric steering mechanism to the hydraulic steering mechanism (S**110**).

The present exemplary embodiments are thus configured to have a system for controlling steering of an outboard motor (**10**) adapted to be mounted on a stem of a boat (**12**) and having an internal combustion engine that powers a propeller, comprising: a steering wheel (**18**) adapted to be installed at a cockpit of the boat to be turned by an operator; a steering shaft (swivel shaft **14**) installed in the outboard motor through which the outboard motor can be steered relative to the boat; an electric steering mechanism (**20**) having a steering wheel angle sensor (**28**) which produces an output indicative of a turned amount of the steering wheel, a rotation angle sensor (**26**) which produces an output indicative of a rotation angle of the steering shaft, an electric actuator (electric motor **24**) which is adapted to rotate the outboard motor about the steering shaft, and a controller (ECU **30**) which controls operation of the electric actuator in response to the outputs of the steering wheel angle sensor and the rotation angle sensor such that the outboard motor is steered relative to the boat; a manual steering mechanism (**66**) which rotates the outboard motor about the steering shaft through a cable (**70**) in response to turning of the steering wheel such that the outboard motor is steered relative to the boat; and a switch (switching mechanism **346**) which switches steering control between the electric steering mechanism and the manual steering mechanism in response to manipulation by an operator.

In the system, the switch includes: a driver (electromagnetic solenoid **50**, manual knob **58**) disposed to be freely manipulated by the operator; and a clutch (**52**) which connects the steering wheel to the cable in response to manipulation of the driver by the operator such that the manual steering mechanism becomes operative.

In the system, the manual steering mechanism comprises a stay (**68**) installed in the outboard motor and connected to the cable (**70**) and a driving mechanism (**72**) which drives the cable in response to turning of the steering wheel, and the clutch connects the steering wheel to the cable through the driving mechanism.

It should be noted in the above that the first to sixth embodiments are only examples and a combination of several embodiments from among the six embodiments, e.g., a combination of the second and sixth embodiments, can be also applied as another example.

It should be also noted in the above that, although the clutch **52** or electromagnetic clutch **64** is configured to be dog type, a clutch of friction-plate type can instead be used.

It should be further noted in the above that, although only one outboard motor **10** is mounted on the boat **12**, two or more outboard motors **10** can be mounted on the boat **12**.

While the invention has thus been shown and described with reference to specific exemplary embodiments, it should be noted that the invention is in no way limited to the details of the described arrangements; changes and modifications may be made without departing from the scope of the appended claims.

What is claimed is:

**1**. A system for controlling steering of an outboard motor adapted to be mounted on a stern of a boat and having an internal combustion engine that powers a propeller, comprising:

a steering wheel adapted to be installed at a cockpit of the boat to be turned by an operator;

a steering shaft installed in the outboard motor through which the outboard motor can be steered relative to the boat;

an electric steering mechanism having a steering wheel angle sensor which produces an output indicative of a turned amount of the steering wheel, a rotation angle sensor which produces an output indicative of a rotation angle of the steering shaft, an electric actuator which is adapted to rotate the outboard motor about the steering shaft, and a controller which controls operation of the electric actuator in response to the outputs of the steering wheel angle sensor and the rotation angle sensor such that the outboard motor is steered relative to the boat;

a hydraulic steering mechanism having a hydraulic actuator which is adapted to rotate the outboard motor about the steering shaft and a hydraulic pump which supplies operating oil to the hydraulic actuator in response to turning of the steering wheel such that the outboard motor is steered relative to the boat; and

a switch which switches steering control between the electric steering mechanism and the hydraulic steering mechanism in response to manipulation by an operator, wherein the switch includes:

a driver disposed to be freely manipulated by the operator; and

a clutch which disconnects the hydraulic pump from the hydraulic actuator in response to manipulation of the driver by the operator, such that the hydraulic steering mechanism becomes inoperative.

**2**. The system according to claim **1**, wherein the driver includes:

a tab switch disposed to be freely manipulated by the operator; and

an electromagnetic solenoid which is energized/de-energized in response to manipulation of the tab switch by the operator;

and the clutch disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the tab switch.

**3**. The system according to claim **2**, wherein the driver includes:

a manual knob disposed to be freely manipulated by the operator;

and the clutch disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the manual knob.

**4**. The system according to clam **2**, further including:

an oil-path opening/closing mechanism which closes an oil path connecting the hydraulic pump and the hydraulic actuator when the clutch disconnects the hydraulic pump from the hydraulic actuator.

**5**. The system according to claim **1**, wherein the driver includes:

a tab switch disposed to be freely manipulated by the operator; and

an electric motor which is rotated in response to manipulation of the tab switch by the operator;

and the clutch disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the tab switch.

**6**. The system according to claim **5**, wherein the driver includes:

a manual knob disposed to be freely manipulated by the operator;

and the clutch disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the manual knob.

**7**. The system according to clam **5**, further including:

an oil-path opening/closing mechanism which closes an oil path connecting the hydraulic pump and the hydraulic actuator when the clutch disconnects the hydraulic pump from the hydraulic actuator.

**8**. The system according to claim **1**, wherein the driver includes:

a tab switch disposed to be freely manipulated by the operator;

and the clutch disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the tab switch.

9. The system according to claim 8, wherein the driver includes:

a manual knob disposed to be freely manipulated by the operator;

and the clutch disconnects the hydraulic pump from the hydraulic actuator in response to the manipulation of the manual knob.

10. The system according to clam 8, further including:

an oil-path opening/closing mechanism which closes an oil path connecting the hydraulic pump and the hydraulic actuator when the clutch disconnects the hydraulic pump from the hydraulic actuator.

11. The system according to claim 1, further including:

a clutch position sensor which produces an output indicative of a position of the clutch;

and the controller determines whether the hydraulic actuator is in operation based on the output of the clutch position sensor.

12. The system according to claim 1, wherein the electric actuator comprises an electric motor which rotates the steering shaft through a gear mechanism.

13. The system according to claim 1, wherein the electric actuator comprises an electrically-operated hydraulic pump which rotates the steering shaft through the hydraulic actuator of the hydraulic steering mechanism.

14. A system for controlling steering of an outboard motor adapted to be mounted on a stern of a boat and having an internal combustion engine that powers a propeller, comprising:

a steering wheel adapted to be installed at a cockpit of the boat to be turned by an operator;

a steering shaft installed in the outboard motor through which the outboard motor can be steered relative to the boat;

an electric steering mechanism having a steering wheel angle sensor which produces an output indicative of a turned amount of the steering wheel, a rotation angle sensor which produces an output indicative of a rotation angle of the steering shaft, an electric actuator which is adapted to rotate the outboard motor about the steering shaft, and a controller which determines a desired steering angle based on the output of the steering wheel angle sensor and controls operation of the electric actuator to steer the outboard motor relative to the boat such that a detected steering angle detected from the output of the rotation angle sensor becomes equal to the desired steering angle;

a hydraulic steering mechanism having a hydraulic actuator which is adapted to rotate the outboard motor about the steering shaft and a hydraulic pump which supplies operating oil to the hydraulic actuator in response to turning of the steering wheel such that the outboard motor is steered relative to the boat; and

a switch which switches steering control between the electric steering mechanism and the hydraulic steering mechanism;

wherein the controller determines whether an error between the detected steering angle and the desired angle is equal to or greater than a predetermined value, and operates the switch in response to the determination.

15. The system according to claim 14, wherein the controller determines that a failure has occurred in the electric steering mechanism when the error is equal to or greater than the predetermined value, and operates the switch to switch the mechanism from the electric steering mechanism to the hydraulic steering mechanism.

16. The system according to claim 14, wherein the electric actuator comprises an electric motor which rotates the steering shaft through a gear mechanism.

17. The system according to claim 14, wherein the electric actuator comprises an electrically-operated hydraulic pump which rotates the steering shaft through the hydraulic actuator of the hydraulic steering mechanism.

18. A system for controlling steering of an outboard motor adapted to be mounted on a stern of a boat and having an internal combustion engine that powers a propeller, comprising:

a steering wheel adapted to be installed at a cockpit of the boat to be turned by an operator;

a steering shaft installed in the outboard motor through which the outboard motor can be steered relative to the boat;

an electric steering mechanism having a steering wheel angle sensor which produces an output indicative of a turned amount of the steering wheel, a rotation angle sensor which produces an output indicative of a rotation angle of the steering shaft, an electric actuator which is adapted to rotate the outboard motor about the steering shaft, and a controller which controls operation of the electric actuator in response to the outputs of the steering wheel angle sensor and the rotation angle sensor such that the outboard motor is steered relative to the boat;

a manual steering mechanism which rotates the outboard motor about the steering shaft through a cable in response to turning of the steering wheel such that the outboard motor is steered relative to the boat; and

a switch which switches steering control between the electric steering mechanism and the manual steering mechanism in response to manipulation by an operator,

wherein the switch includes:

a driver disposed to be freely manipulated by the operator; and

a clutch which connects the steering wheel to the cable in response to manipulation of the driver by the operator, such that the manual steering mechanism becomes operative.

19. The system according to claim 18, wherein the manual steering mechanism comprises a stay installed in the outboard motor and connected to the cable and a driving mechanism which drives the cable in response to turning of the steering wheel, and the clutch connects the steering wheel to the cable through the driving mechanism.

20. The system according to claim 18, wherein the electric actuator comprises an electric motor which rotates the steering shaft through a gear mechanism.

21. The system according to claim 18, wherein the electric actuator comprises an electrically-operated hydraulic pump which rotates the steering shaft through the a hydraulic actuator of the hydraulic steering mechanism.

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